Idaho National Laboratory Research & Development

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- National & Energy Security
- Collaborations
- New Capabilities
- Advancing Technology
- Education & University Partnerships

ON THE COVER

TRISO nuclear fuel particle research at INL.
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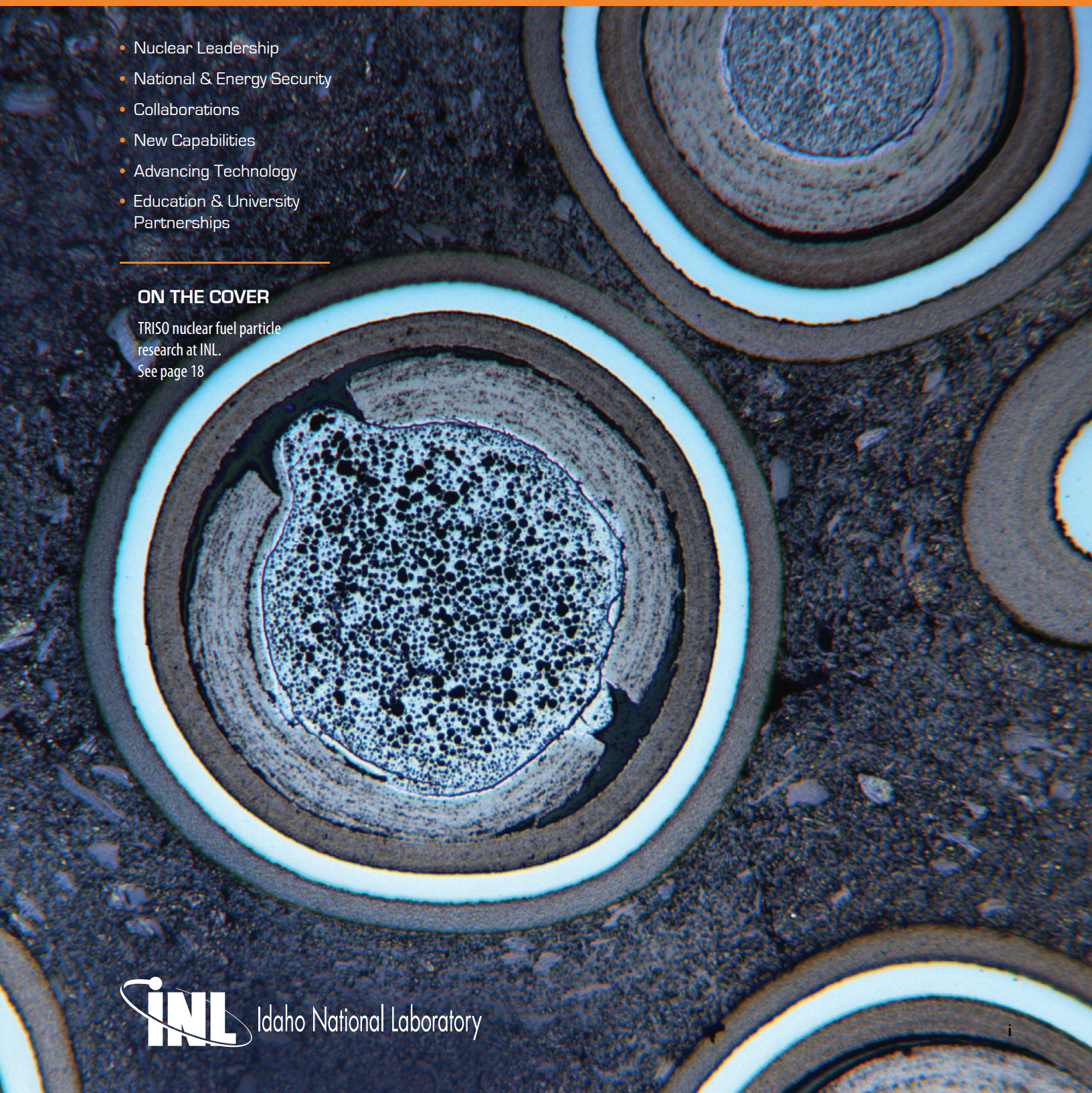

INL Idaho National Laboratory

FROM THE Director

John Grossenbacher
Director, Idaho National Laboratory

January 2014

Technological innovations that drive economic growth require both public and private investment. The U.S. Department of Energy's national laboratories play a crucial role by conducting the type of research, testing and evaluation that is beyond the scope of regulators, academia or industry. Examples of such work from the past year can be found in these pages.

Idaho National Laboratory's engineering expertise and applied science focus spur innovation and help deploy new technologies for nuclear energy, national security and new energy resources. Unique infrastructure, nuclear material inventory and vast expertise converge at INL, the nation's nuclear energy laboratory. Productive partnerships with academia, industry and government agencies deliver high-impact outcomes.

This edition of INL's Impacts magazine highlights our newest leadership efforts, capabilities, collaborations, research accomplishments and university partnerships. Please take a few minutes to learn more about the critical resources and transformative innovations at one of the nation's premier applied science laboratories.

On the cover
INL leads research efforts to test advanced TRISO nuclear fuel, which has several layers of carbon and carbide that serve as the primary containment for radioactive material. Read more on page 18.

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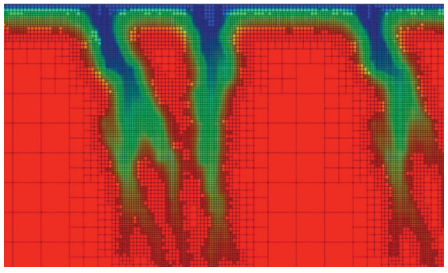

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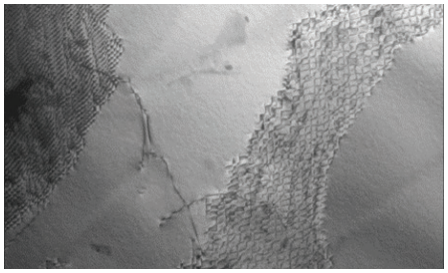

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AN APPLIED Science Resource

The U.S. today faces a number of challenges related to energy security, national security and cybersecurity. The Department of Energy (DOE) multiprogram national labs are especially suited to find solutions that may be beyond the ability of industry, academia or regulators to tackle alone.

As the lead laboratory for the DOE's Office of Nuclear Energy (DOE-NE), Idaho National Laboratory (INL) hosts the nation's critical nuclear energy research infrastructure. The lab supplements this core mission with expertise in national security and advanced energy technologies. INL is distinct within the U.S. national laboratory complex for its strong focus on engineering and applied science, which helps reduce risks associated with deploying new concepts for large-scale, real-world use.

Exceptional expertise, strategic partnerships and growing one-of-a-kind testing abilities converge here to create an incubator that helps new ideas mature toward the marketplace. Enabling access by researchers beyond INL is a necessary and proper use of the resources entrusted to our stewardship. INL embraces the user facility model that hosts distinctive capabilities and makes them available to researchers across the nation.

Collaborations
Throughout the publication, the symbols below denote projects involving external collaborations with:

- Universities
- Other national labs
- International entities
- Private industry
- Government entities

Consider INL's skilled personnel and extensive partnerships, and a picture emerges of a national resource capable of addressing numerous current and future national challenges.

For example, INL has partnered with researchers at other national labs to evaluate the safety and performance of an advanced reactor design and to analyze how advanced nuclear fuel particles stand up to heat exceeding accident conditions. Research agreements with entities spanning the nuclear energy enterprise enable INL to share expertise and research tools that are most relevant to private industry.

INL also hosts test beds for technology ranging from wireless communications to biofuels feedstock processing. This year, the lab's Wireless Test Bed and Biomass Feedstock Processing assets were both designated as national user facilities.

Exceptional expertise, strategic partnerships and growing one-of-a-kind testing abilities converge here to create an incubator that helps new ideas mature toward the marketplace.

Examples in the pages that follow illustrate INL's leadership related to nuclear energy, national security and advanced energy systems.

Numerous partnerships from the past year are highlighted, along with enhancements to INL's state-of-the-art testing and evaluation capabilities. A small sampling of the lab's science and technology research is described in the Advancing Technology section. Examples of our partnerships with universities and Idaho's school system are described starting on page 30. The final pages give a snapshot of INL's many unique characteristics.

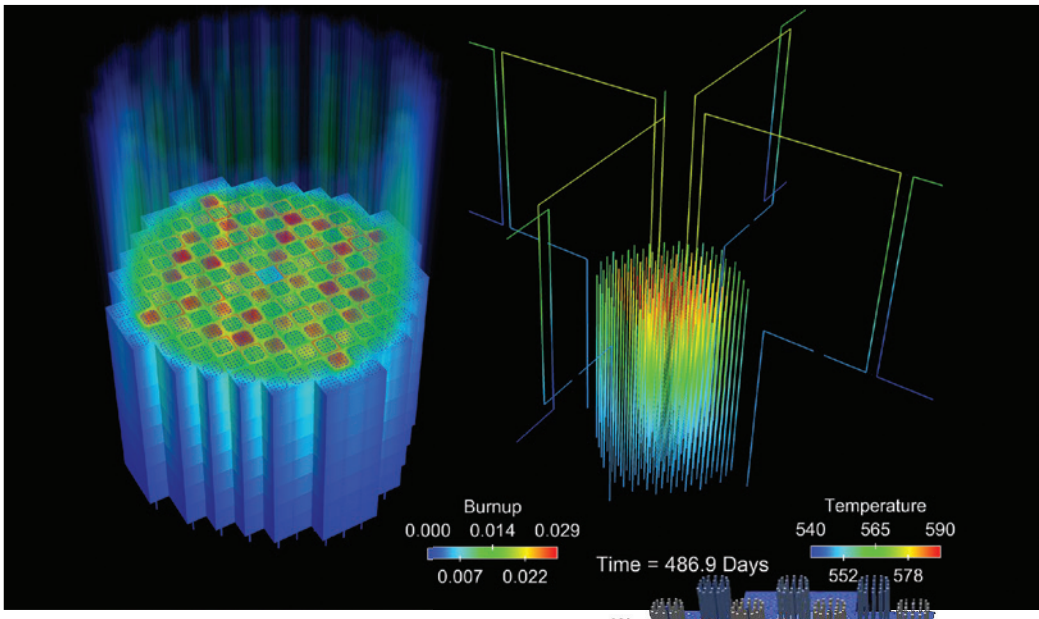
Overall, this partial summary of recent achievements illustrates how INL research innovation, testing and evaluation is helping apply new energy solutions to safely, securely and sustainably advance nuclear energy, protect infrastructure, expand energy supply and improve efficiency.

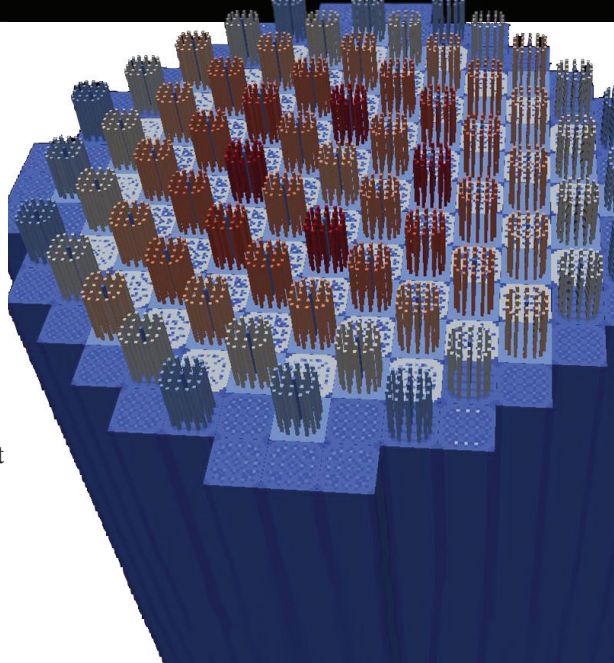
NUCLEAR Leadership

The Nation's Nuclear Energy Laboratory

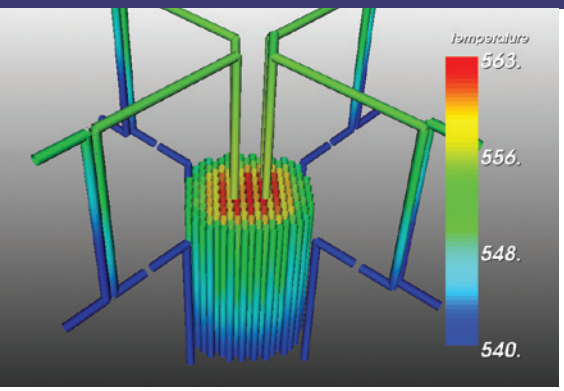
INL has led a fundamental shift in approach to nuclear research and development at national labs and universities. The approach helps the Department of Energy's Office of Nuclear Energy (DOE-NE) unite scientists and engineers with the world-class capabilities and unique facilities needed to conduct transformational nuclear research, development and demonstrations. Combining physical theory, advanced modeling and simulation, and small-scale experiments reduces uncertainty when irradiation testing or demonstrations are necessary.

Both the Electric Power Research Institute (EPRI) and Westinghouse Electric Company have joined the MOOSE user community.





Demonstrating full-core simulation
Building a useful simulation capability has traditionally required a team of software developers working for years with scientists to describe a given phenomenon. INL's MOOSE (Multiphysics Object Oriented Simulation Environment) now enables simulation tools to be developed with a fraction of the resources previously required. In Fiscal Year 2013, INL publicly demonstrated MOOSE's robust nature and flexibility with a full-core reactor simulation (above and right).



MOOSE simulated the performance of a light water reactor core over multiple operating cycles. Each fuel rod in a full-sized reactor core was modeled using individual fuel performance calculations running simultaneously to solve equations describing numerous physical properties. MOOSE-based micro- and macro-scale fuel performance codes were coupled with models for neutronics, thermal-hydraulics, and formation of byproduct deposits.

Demonstrating that MOOSE could be used to solve this previously intractable problem generated enormous interest from DOE and industry modeling/simulation communities. Dr. Pete Lyons, DOE's Assistant Secretary for Nuclear Energy, indicated an intention to explore expanded application of MOOSE-based model development with programs such as the Consortium for Advanced Simulation of Light Water Reactors (CASL).

Studying accident scenarios

One of the industry's premier modeling tools for reactor and fuel development is the Reactor Excursion and Leak Analysis Program (RELAP) developed at INL. The next generation of this program (RELAP-7, left) includes first-of-a-kind simulation capabilities that are unavailable in existing nuclear power plant system safety analysis codes. The deployment of RELAP-7 is supported by the MOOSE-based RAVEN code, which provides a mature graphical user interface and a cutting-edge probabilistic analysis environment. As proof of its capabilities, RELAP-7 successfully simulated a simplified station-blackout accident scenario, which is what the Fukushima plant experienced after a historic 2011 tsunami.

INL co-hosted the Global 2013 international nuclear fuel cycle conference, an important biennial gathering of international experts and stakeholders. INL leaders served as the conference's general chair, technical program chair and in numerous organizing roles. About 425 people from 23 countries attended this year's conference.

NUCLEAR Leadership

Enhancing industry research
Although universities have abundant access to research facilities, private companies have fewer options when they need complex, high-end capabilities to advance new technology. That's where public resources such as the DOE's national laboratory complex play a role.

The Advanced Test Reactor National Scientific User Facility (ATR NSUF), which already provides access to university scientists, is now demonstrating how industry researchers can access INL's distinctive capabilities. Examples are two research projects with the Electric Power Research Institute (EPRI) — a nonprofit research, development and demonstration organization for the electric utility industry. One project will provide data that could help increase the robustness of the cladding materials surrounding and isolating nuclear fuel. Another boosts understanding of factors that can limit the lifetimes of reactor structural materials. The ATR NSUF's Industry Advisory Committee meets annually to ensure the user facility offers capabilities needed to support industry experiments.

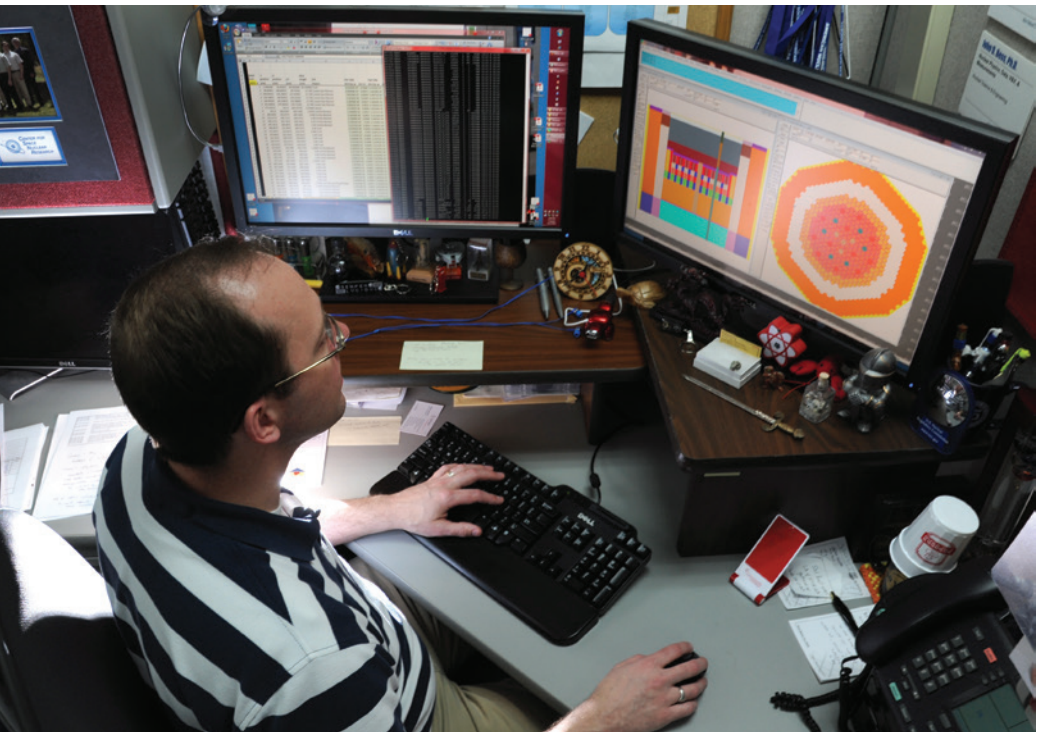
In 2013, Westinghouse Electric Company LLC became the first private company to join the ranks of ATR NSUF partner facilities. The addition of Westinghouse, a leading supplier of nuclear plant products and technologies, provides ATR NSUF researchers access to an even wider variety of capabilities for nuclear materials and fuels research. As an ATR NSUF partner, Westinghouse offers its Materials Center of Excellence Laboratories (MCOE) Hot Cell Facility (left) and accompanying laboratories to provide experimental support to ATR-related nuclear energy materials research programs.

A Westinghouse Electric Company hot cell facility (left) is now partnered with the Advanced Test Reactor National Scientific User Facility. INL researchers (right) helped analyze an advanced reactor design.

Evaluating advanced designs

Engineers at DOE national labs helped the world's nuclear experts evaluate a new nuclear reactor design that could increase safety margins while reducing waste. France's Atomic Energy and Alternative Energies Commission (CEA) collaborated with nuclear engineers at DOE's INL and Argonne National Laboratory for the project. Their goal: assess safety and performance parameters for a new fast reactor design.

The Advanced Sodium Technological Reactor for Industrial Demonstration (ASTRID) design offers inherent protection because the fission process would actually slow down naturally even if the reactor shutdown capability is lost. But before such a reactor can be built, those safety assumptions need to be checked and rechecked. CEA partnered with DOE to have two national labs independently analyze the reactor core performance parameters and safety characteristics under defined scenarios. INL evaluated reactor physics — how neutrons behave in the reactor core during operation — using its latest data set describing neutron cross sections, as well as its state-of-the-art analysis codes. INL supplied this information to Argonne analysts, who evaluated safety margins under specific loss-of-flow and loss-of-heat-sink scenarios. Blind comparison of the independent French and American analyses showed agreement, bolstering confidence in the safety predictions.



Supporting global research collaboration

The Generation IV International Forum (GIF) is a cooperative international endeavor organized to carry out the research and development required for next-generation nuclear energy systems. INL employees provided critical support to the organization's chairman, including leading the organization of meetings in Beijing (above) and Brussels. INL staff also led an update and redesign of the GIF's public website and organized a special issue of the Journal of Progress in Nuclear Energy dedicated to Gen-IV.

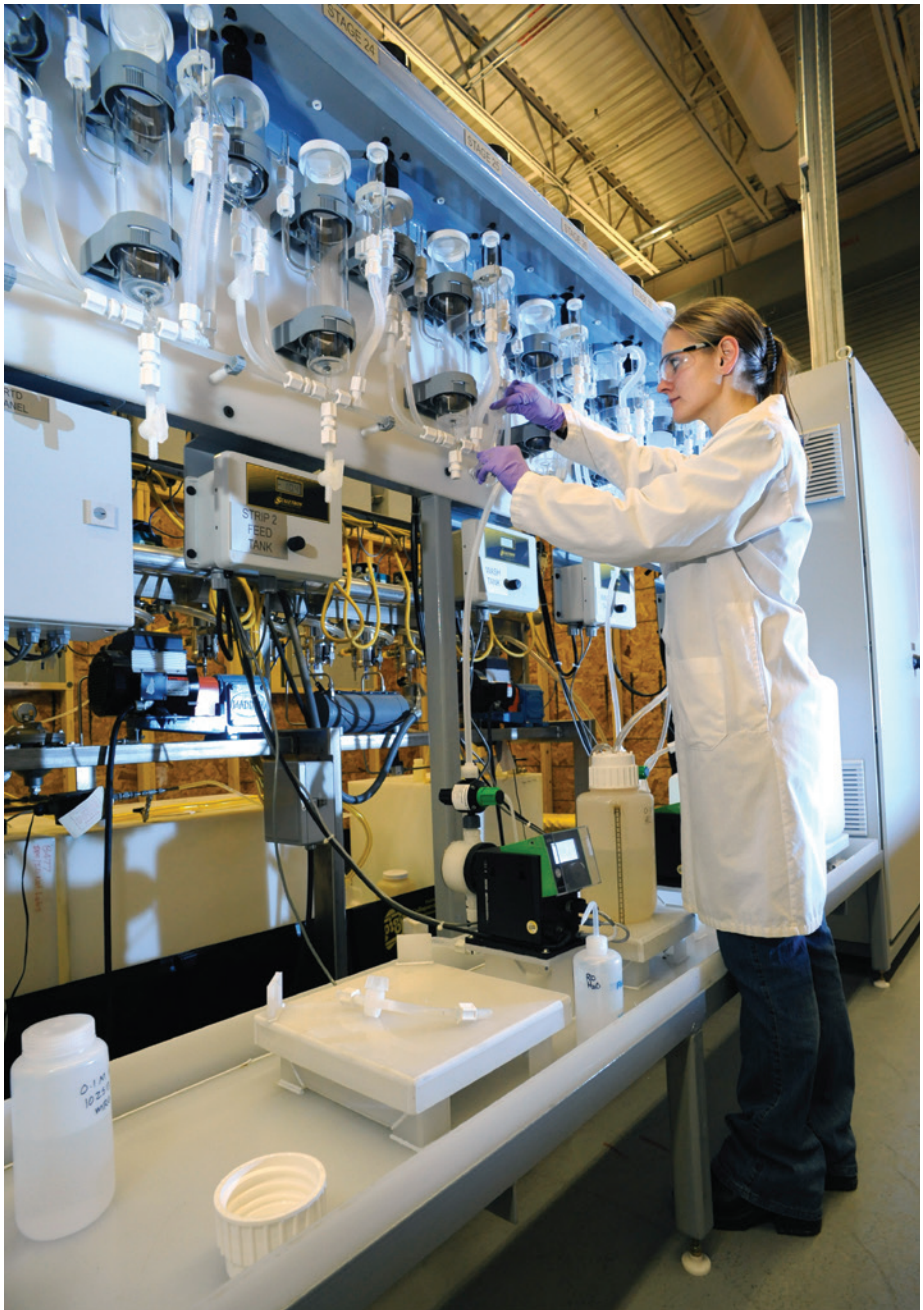
NATIONAL AND ENERGY Security

Research spanning the spectrum

INL is a multiprogram national lab that supports national security and new energy solutions. INL's isolated site, test bed infrastructure and applied science focus are ideal for experimentation, assessments and demonstrations that help deploy new technology to protect the nation's natural resources and critical infrastructure.

Recovering critical materials
So-called rare earth elements are deeply embedded in everything from fluorescent light bulbs to smartphones — and they're critical for electric vehicles, wind turbines and solar panels. But these materials are subject to supply disruptions. The DOE established an Energy Innovation Hub that will develop solutions to the domestic shortages of rare earth metals and other materials critical for U.S. energy security. The new Critical Materials Institute (CMI) led by Ames National Laboratory brings together leading researchers from academia, four DOE national laboratories and the private sector.

INL leads research efforts to develop new processes for recovering and recycling critical elements from waste streams such as lighting systems, electronics and large permanent magnets. This selection is a testament to INL's strengths in separations science, nuclear science and technology, chemical and biological sciences, geosciences, and materials science.



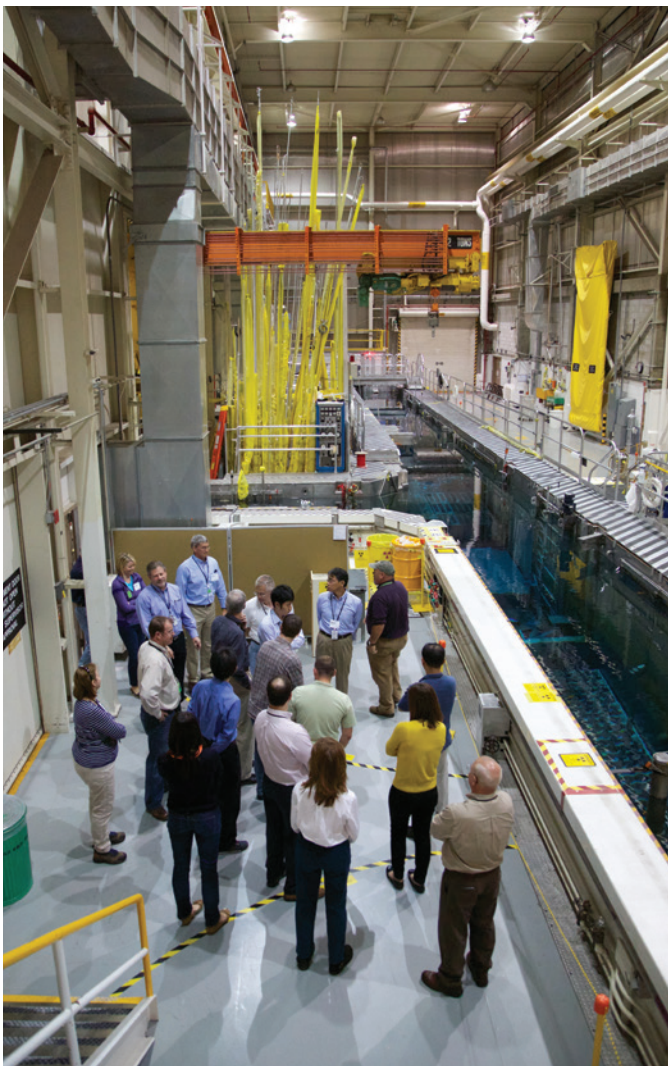
Modeling renewable energy integration

A modern electric power grid needs to effectively utilize renewable energy sources, distributed generation, and demand response programs while accommodating plug-in hybrid electric vehicles and other energy-efficient technologies. Such modernization efforts need to be integrated while increasing the national power grid's reliability and resilience. INL hosts a suite of modeling and simulation tools to study the potential power grid implications of these new technologies. At the top of the tool set: The Real Time Digital Simulator (RTDS) provides simulation technology for fast, reliable, accurate, and cost-effective study of power systems with complex High Voltage Alternating or Direct Current (HVAC and HVDC) networks. The ability to both simulate real-time power grid dynamics and test physical devices (hardware-in-the-loop) on a full-scale grid is a key factor in detecting previously unknown vulnerabilities and helping emergency personnel plan responses for grid failures.

NOTABLE Collaborations

Sharing access to national capabilities

National labs exist partially to conduct research and development that isn't right for industry or academia. Close partnerships with these entities provide access to public research capabilities and help transition research into nationally significant results. University partnerships and collaborations with industry help INL advance energy research, production and safety by providing access to INL capabilities, analysis and expertise.



Supporting industry innovation
Transformative innovation often requires research infrastructure that is beyond the reach of for-profit companies. The DOE's national laboratory system stewards vital scientific and engineering capabilities that can support such innovation. Two high-profile visits in 2013 illustrate the value INL offers to the nuclear energy industry.

Bill Gates, American business magnate and chair of the nuclear reactor startup company TerraPower LLC visited INL in October (right). TerraPower has engaged INL to support certain aspects of design for the company's traveling wave reactor. Gates' visit focused on the lab's expertise and capabilities.

Members of the Nuclear Energy Institute (NEI), the nuclear energy industry's policy organization, also toured INL (left) to see the laboratory, meet its scientists and engineers, and tour its distinctive research facilities. The tour group included representatives from nine U.S. and international companies representing numerous aspects of the nuclear energy industry.

"TerraPower has many cooperative projects and lots of partnerships, but our work with INL is singularly important."

— Bill Gates, TerraPower LLC board chairman, during a visit to Idaho National Laboratory

NOTABLE Collaborations

Enabling specialized radiological research

Some of today's most critical questions in nuclear materials science require access to highly specialized research tools. The Microscopy and Characterization Suite (MaCS) in the Center for Advanced Energy Studies at INL boasts a collection of equipment that is open to external researchers and supports advanced microscopy for both radiological and nonradiological materials.

Throughout the summer of 2013, the MaCS suite was booked for an average of 15 hours per day by research scientists from more than 10 universities in six states and one foreign country. Researchers from private industry, including Micron and Atomic Energy of Canada Limited, also are regular MaCS users. The INL-based Advanced Test Reactor National Scientific User Facility (ATR NSUF) helped create the MaCS, which is overseen by instrument leads from Boise State University.

Upgrading control rooms

The DOE's Human System Simulation Laboratory (HSSL) at Idaho National Laboratory is a full-scale virtual nuclear control room that can verify the safety and reliability of proposed technology refurbishments as they are being designed for implementation in commercial nuclear plant control rooms. This one-of-a-kind control room simulator is specifically designed to facilitate digital renovation of existing plants, which predominantly use analog systems. The INL lab also enables scientists to improve control-room designs by studying human interactions with control room instrumentation and systems as operators would use them in the actual plant. The facility is now helping Duke Energy embark on an upgrade project for several of its nuclear plant control rooms.

The most sought-after MaCS equipment includes: a Focused Ion Beam, Transmission Electron Microscope, Local Electrode Atom Probe and a Scanning Electron Microscope (left). The feedstock Process Demonstration Unit at INL (upper right) is part of a new National User Facility.

Solving biofuels challenges
Widespread use of cost-competitive, high-performance biofuels will require a national transformation to produce abundant biomass resources. The DOE Bioenergy Technologies Office has shaped the vision for a national, commodity-scale supply system for bioenergy feedstocks. In July 2013, DOE's Office of Energy Efficiency and Renewable Energy designated INL's biomass research facilities as the Biomass Feedstock National User Facility which invites more industry collaboration.

The BFNUF, for short, is a premier U.S. facility for scientific and technical investigation of biomass feedstock evaluations, preparation and transformation. The BFNUF includes the feedstock Process Demonstration Unit (PDU), the state-of-the-art feedstock characterization analytical laboratory and the Biomass Resource Library. The BFNUF already has partnered with two commercial users (Forest Concepts, LLC of Seattle, Wash., and Vortex Processing Inc. of Dallas-Fort Worth, Texas) to perform studies to develop new processes that reduce the size of solid materials by crushing, grinding or other methods.

Improving communications security
Solving national wireless and spectrum challenges will require improvements in infrastructure security, communications interoperability, spectrum utilization and wireless technologies reliability. In May 2013, DOE designated INL's Wireless Test Bed as a national user facility, reinforcing INL leadership in full-scale research, development, demonstration and scientific investigation of wireless communications systems. INL's unique capabilities enable commercial, federal and academic scientists to take an integrated research approach.

Among the Wireless National User Facility's new assets: a High Frequency Sounder Capability, which is publishing public data on atmospheric propagation of radio waves. Also, the Wireless Test Bed became the principal control center for the U.S. Department of Defense's Joint Improvised Device Defeat Organization testing program and is acting as strategic technology advisor for next-generation communications challenges.

"With this new Wireless National User Facility, DOE will provide the nation with unmatched research and demonstration capabilities."

— Daniel Poneman, U.S. Deputy Secretary of Energy

Capabilities

Strategic Infrastructure

In the past year, INL has continued adding to an irreplaceable array of capabilities that work toward achieving the strategic infrastructure outlined in the lab's Ten-Year Site Plan. The full complement of capabilities enables INL to respond to today's nuclear energy challenges, serve as a multiprogram laboratory with broad competencies in energy and national security, and address future challenges.

The IASCC system test equipment includes shielded hot cells, water boards for chemistry control, a data acquisition system, ventilation systems, and miscellaneous tools and handling equipment.

Studying stress corrosion cracking
Understanding the degradation of materials irradiated in a reactor environment is critical to ensuring the continued safe and reliable operation of the existing light water reactor fleet and making improvements in materials for advanced reactor systems. Gaining a better understanding of irradiation-assisted stress corrosion cracking (IASCC) in reactor materials was ranked by industry as its top research priority. Yet only a few IASCC systems have been built in the United States, and the existing systems are not adequate to perform all the testing required by industry and the Nuclear Regulatory Commission.

The ATR National Scientific User Facility funded the installation of two IASCC test rigs at INL's Materials and Fuels Complex, providing a significant new capability for the United States. Test results will be used to determine the reaction of the sample material to the environment found in a nuclear reactor and calculate the life of existing and future nuclear reactors.

Enabling nuclear research

A number of new capabilities were demonstrated at INL's Materials and Fuels Complex this year. For example, an INL team used INL-designed and -built equipment to purify roughly 2 grams of americium metal, a rare and expensive element used in many types of household smoke detectors and geological data-gathering equipment. Studies of the pure metal can help researchers understand the physical properties of fuels containing americium. No other DOE laboratory has demonstrated this capability, which can ultimately lead to the understanding of how much americium can be in transmutation fuels that have the potential to reduce the volume and toxicity of material destined for repositories.

Technicians at MFC also established an ability to accelerate the fuel fabrication process and to create new fuel types for experiments. MFC operators demonstrated the first direct machining of uranium metal at INL. They are now able to work directly on enriched metallic uranium to rapidly make precision experimental fuels. High-precision metallic fuel samples made of enriched uranium enable researchers to test new fuel shapes and expand the research options available to DOE and industry.

The new Energy Innovation Laboratory at INL will host both diverse research activities and public conference facilities.

Enhancing research facilities

World-class research requires world-class facilities such as the brand new 148,000-square-foot Energy Innovation Laboratory on INL's Research and Education Campus. Construction concluded in 2013, and researchers are now moving into the building, which will co-locate DOE program space with user facilities and a public, multiuse auditorium. The U.S. Green Building Council certified the building as LEED Platinum, the first INL building to achieve the top level of sustainable building design and only the fourth platinum commercial building in the state. Leadership in Energy and Environmental Design (LEED) is the industry standard for Green Building Validation.

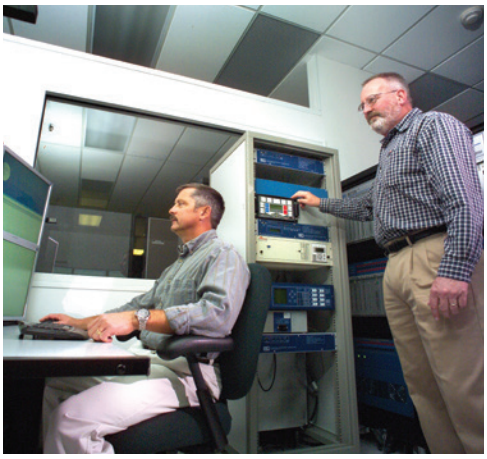
Capabilities

Protecting water systems
The Environmental Protection Agency works with water utilities to protect domestic water supplies and clean up systems that become contaminated. Purposeful or inadvertent contamination can require cleaning large amounts of water and infrastructure. The EPA places high priority on advancing drinking water security through the science and engineering of detection, monitoring, pipe system decontamination and safe disposal of large volumes of contaminated water.

To help address these science gaps, agency researchers developed the Water Security Test Bed at INL. The WSTB, which is unique in the U.S., will replicate a typical municipal drinking water piping system in a roughly 200-foot by 400-foot grid using 40-year-old, eight-inch ductile iron pipe. Researchers are building the grid above ground for easy access during experiments.

Lab- and pilot-scale approaches to contamination detection, infrastructure decontamination and water treatment can be demonstrated at this full-sized test bed using agents that simulate biological, chemical or radioactive materials. Experimental treatments may include chlorination and flushing protocols, advanced oxidative processes, or emptying and fumigating pipes. The first test bed experiment will be conducted in FY 2014. Test bed research will be available to additional potential collaborators such as agencies within the Department of Defense, the Department of Homeland Security, universities, water utilities and foundations interested in water security research.

Radiological emergency training
The nation needs the ability to train our emergency responders and to test technologies that counter the threat of nuclear and radiological weapons of mass destruction. Yet access to nuclear and radiological materials and realistic training venues are currently limited and costly to establish. The Nuclear & Radiological Activity Center (NRAC) at INL provides users access to a broad range of nuclear and radiological materials, facilities, dedicated test ranges and technical expertise established over more than 60 years of INL's history.



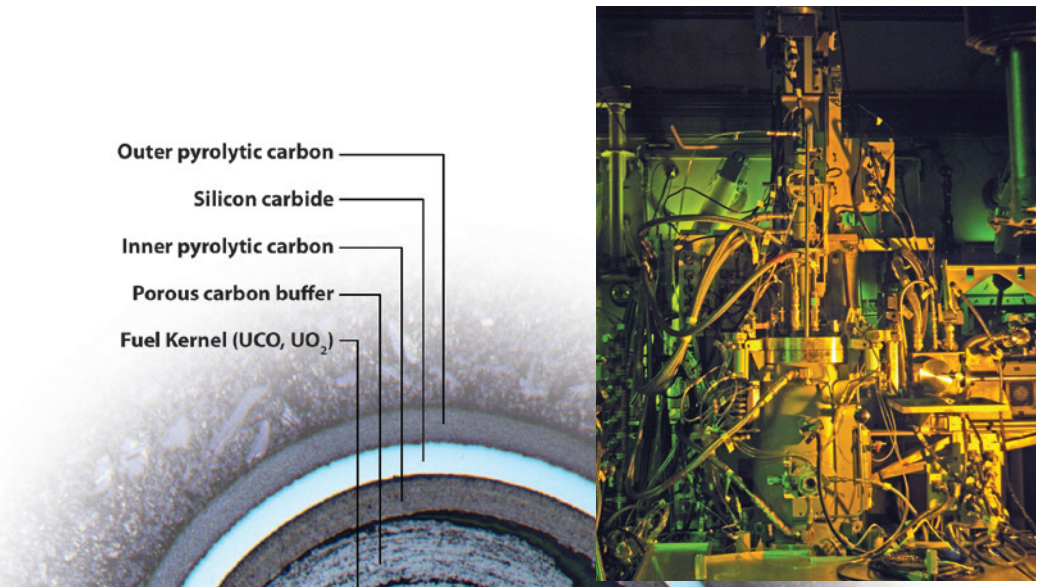
NRAC is able to develop and deliver specific, user-defined exercises to meet the needs of a range of research customers. Located in remote portions of INL's desert Site, the NRAC ranges are isolated and secure. Key features include:

- Two ranges with nearly 900 acres of training space for exercises involving contamination
- The ability to include large radiological sources, special nuclear materials and mock-ups
- Both open-air spaces and industrial buildings
- Full-scale power and wireless communications test beds
- A large low-background area for radiation measurement technology evaluation
- Live-fire explosives testing capabilities
- Support for aerial measurements and ground sampling
- Authorized environmental and safety permits

ADVANCING Technology

A science and engineering asset

Through research innovation, testing and evaluation, INL helps industry apply new energy solutions. INL is a science-based, applied engineering national laboratory dedicated to supporting national missions in nuclear and energy research, applied science and national defense. As a strong multiprogram national laboratory, INL is internationally recognized as a valuable science and engineering asset. The next several pages describe some recent achievements.



Testing next-generation nuclear fuel
Next-generation nuclear reactor fuels are designed to be more efficient and resistant to accident conditions. Scientists working to test and confirm such assumptions made several significant discoveries this year related to one type of advanced fuel called tristructural isotropic (TRISO) fuel, which could run high-temperature gas-cooled reactors (HTGRs).

Researchers at INL and Oak Ridge National Laboratory are analyzing TRISO fuel subjected to extreme temperatures (INL furnace at left). The research team found that TRISO fuel is even more robust than expected. Even at 1,800 degrees Celsius (more than 200 degrees C higher than postulated accident conditions), most fission products remained inside the fuel particles.

Silver is one of the few fission products that can migrate outside the particles, and scientists want to better understand such movement. An INL research team reached a milestone this year by discovering where silver congregates inside irradiated TRISO fuel particles. The discovery was made using specialized equipment in the Materials and Characterization Suite, which is part of the Center for Advanced Energy Studies at INL (more on pp. 12 and 28).

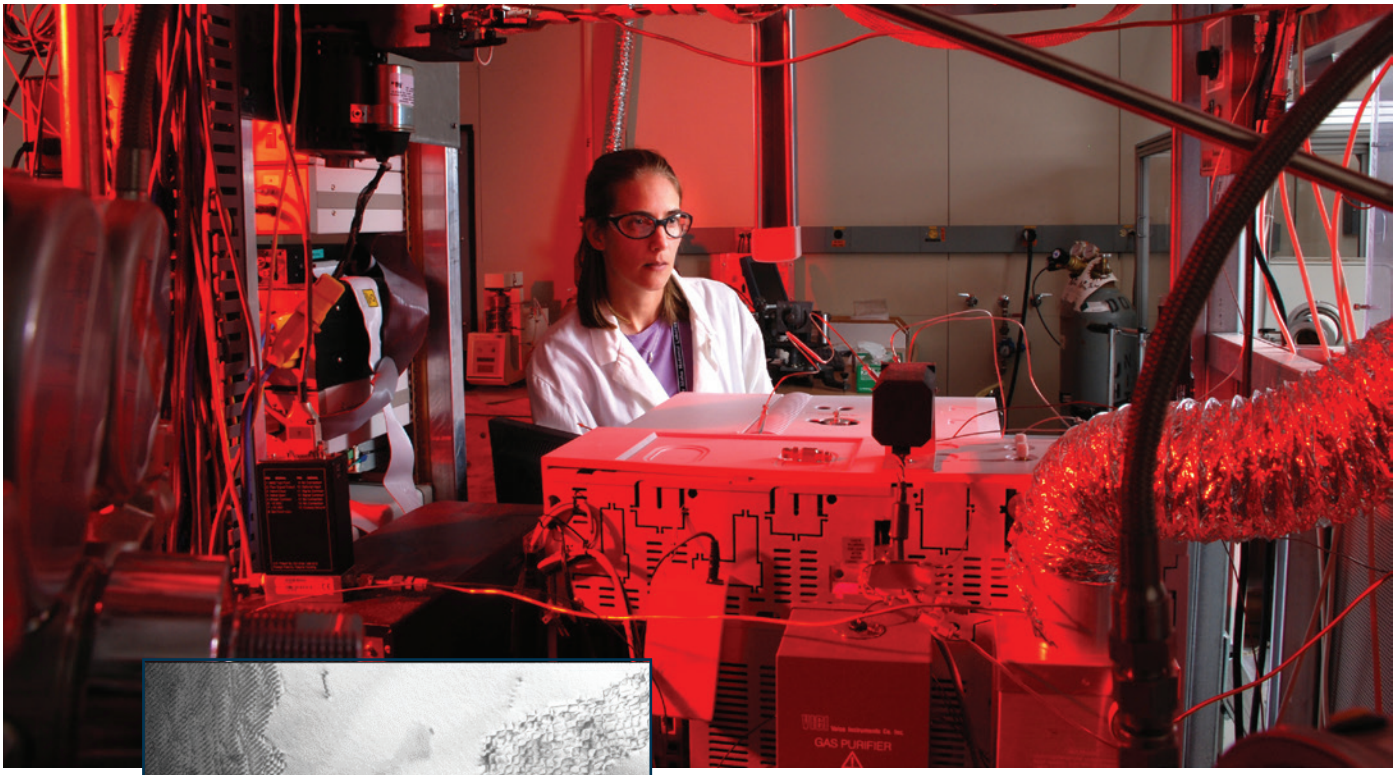
Characterizing irradiation stress
Graphite — the stuff of pencil lead — plays a big role in some next-generation nuclear reactor designs. Besides helping neutrons achieve optimal chain-reaction speed, graphite has a huge heat-absorbing capacity that can keep nuclear fuel at safe temperatures during unexpected events. INL scientists are working with Oak Ridge National Laboratory to characterize the physical limits of different grades of graphite. Of six planned irradiation test series, the team has completed post-irradiation examination of the first set and irradiation of the second set. More than 400 irradiated graphite specimens were thermally, mechanically and physically tested in the first test series. The work is the largest and most complete nuclear graphite research program currently operating. The effort also is the only one in the world examining "irradiation induced creep" on multiple graphite grades, the material property most responsible for predicting the length of time a graphite component can safely stay in the reactor.

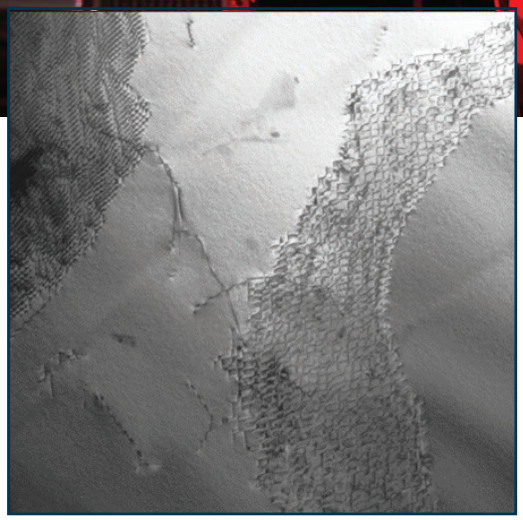
Recognizing expertise

Melissa Teague
The fuel performance and design scientist was recognized with the Young Scientist Award at the European Materials Research Society (E-MRS) Spring Symposium in Strasbourg, France. She was also one of a dozen women nationally honored at the Massachusetts Institute of Technology's Rising Stars in Nuclear Science and Engineering Symposium.

Shannon Bragg-Sitton
The senior nuclear engineer was selected as deputy national technical director for DOE's Used Fuel Disposition Campaign. Shannon serves in a complementary role in DOE's Fuel Cycle Research & Development Advanced Fuels Campaign as the technical lead for Advanced Light Water Reactor Fuels, where she helps coordinate national research activities related to accident-tolerant fuels.

Jon Carmack
The nuclear engineer was selected as the national technical director for DOE's Advanced Fuels Campaign. Jon investigates and analyzes new types of nuclear fuel to determine how irradiated fuels and materials behave on a microscopic scale. He holds a patent in the method and manufacture of nuclear fuel cladding for space reactors.





New nuclear materials

Some next-generation reactor designs require materials that can withstand higher temperatures than current reactors experience. Alloys in today's nuclear reactors can withstand temperatures up to 750 degrees C, but the next generation of reactors will require materials qualified for up to 950 degrees C. One such material is a nickel-based metal alloy called Alloy 617. INL scientists have been gathering data to determine its physical and mechanical properties as a function of temperature, including the effect of welding on mechanical properties. The team is now working to provide the data to the American Society of Mechanical Engineers (ASME), which maintains the "consensus code" that defines material properties such a strength and ductility. Engineers reference this code to ensure a safe design. This effort represents the first attempt in more than 20 years to qualify a new nuclear reactor material.

"INL is recognized as a world leader in producing reference standards to calibrate noble gas measurements for the detection of nuclear explosions."

— U.S. Secretary of Energy Ernest Moniz, recognizing INL's Ultratrace Analysis group for its development of nuclear detection technology that supports treaty verification

Recognizing expertise

Josh Daw
The University of Idaho doctoral candidate working at INL's High Temperature Test Laboratory recently earned first prize in the Fuel Cycle Research Innovations competition for his paper, "Hot Wire Needle Probe for In-Reactor Thermal Conductivity Measurement" (IEEE Sensors, August 2012). Data collected using such a method could lead to improvements for next-generation nuclear reactors.

Laura Carroll
The materials science and engineering researcher earned the INL Laboratory Director's Achievement Award in 2013 for Early Career Exceptional Achievement. Laura leads work to characterize advanced reactor materials and is principal investigator for the Advanced Alloy Testing project under the Small Modular Reactor Advanced Reactor Concepts program.

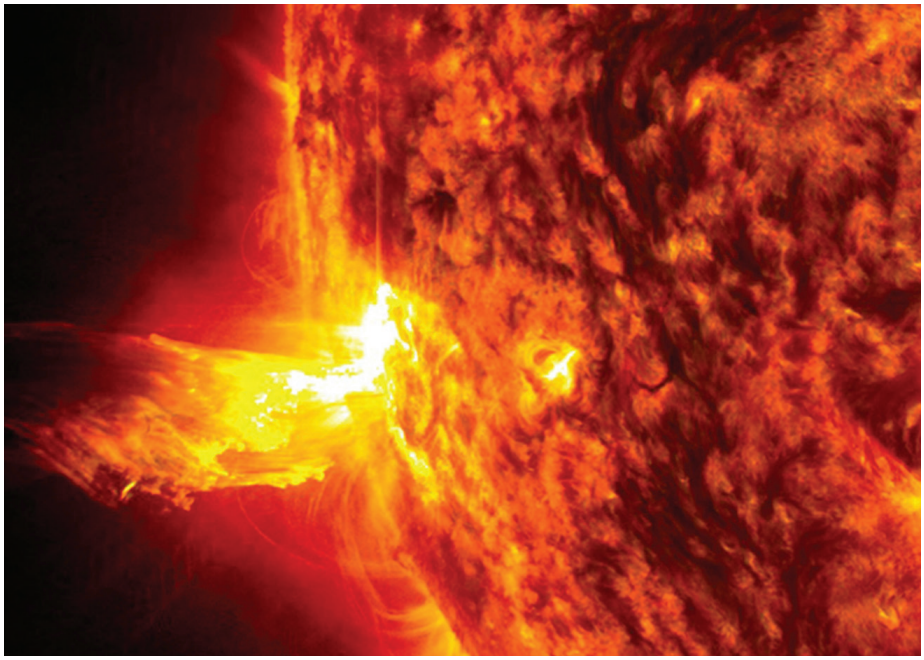
Paul Demkowicz
The distinguished staff scientist received the INL Laboratory Director's Achievement Award in 2013 for Exceptional Engineering Achievement. Paul has worked at INL for nine years on a number of nuclear materials projects. He is the principal investigator for post-irradiation examination and safety testing of TRISO fuel for the Next Generation Nuclear Plant project.

ADVANCING Technology

Experts remove highly enriched uranium from Vietnam's Dalat Nuclear Research Institute, above. At right, a June 20, 2013, eruption of solar material shooting through the Sun's atmosphere. Photo courtesy: NASA's Solar Dynamics Observatory

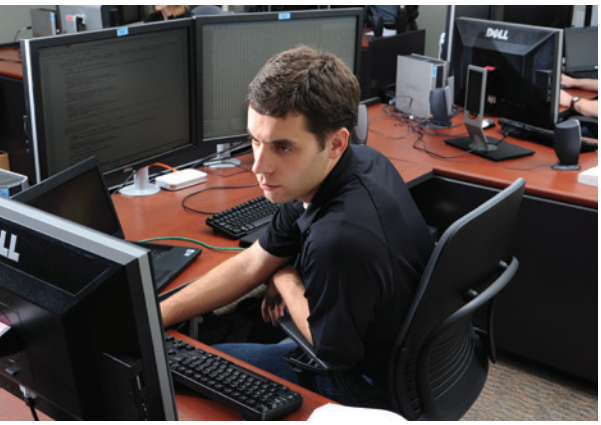
Securing enriched uranium

The Russian-Origin Nuclear Material Removal Program strengthens global nuclear security by safeguarding excess nuclear and radiological materials that could be used by terrorists. INL experts provide strategic support to international efforts. In FY 2013, 11 kilograms of highly enriched uranium (HEU) were removed from the Dalat Nuclear Research Institute in Vietnam (left). More than 49 kilograms of remaining HEU in Hungary were removed and transported to Russia, where it will be downblended into low enriched uranium for use in nuclear power reactors. This makes Vietnam and Hungary the 11th and 12th countries to eliminate HEU from within their borders since President Obama's 2009 announcement of an international effort to secure all vulnerable nuclear material around the world.



Protecting from solar storms

Solar flares and sunspot cycles can disturb or even interrupt power and communications systems for extended periods of time. INL is engaged in first-of-a-kind research and development on its full-scale power grid test bed to understand the effects of such geomagnetic disturbances. Moreover, INL organized and hosted a Geomagnetic Disturbance Workshop. It convened technology and policy speakers from across government, academic and industry sectors to provide a comprehensive view of issues associated with prediction, protection and regulation of the U.S. electric grid from potentially disastrous effects of solar storms.



Bolstering cybersecurity
Critical infrastructure such as utilities and factories must protect physical and computer systems from the threat of cyberattacks. This year, INL evolved its Industrial Control Systems-Mission Support Center (ICS-MSC) from a tactical resource to a strategic leader that is fundamentally changing how the world approaches threats to the complex myriad of cyber-physical systems.

The center deployed groundbreaking methodologies for threat analysis and prioritization of vulnerability assessments for cyber-physical systems. These methods were used in multiple sectors (nuclear, electric power, oil and gas) and across customer sets in the Department of Defense and intelligence community. Under INL leadership, DOE programs are translating strategic threats into technical structures enabling industry to proactively deploy defenses. Through INL's direct leadership on senior government advisory committees, the technical doctrine for the nation's defense from cyber-physical threats has fundamentally changed.

Recognizing expertise

David Chichester
The nuclear engineer was elected to the Institute of Electrical and Electronics Engineers (IEEE) Nuclear & Plasma Science Society's Radiation Instrumentation Steering Committee. David provides national leadership in the area of nuclear nonproliferation instrumentation. His contributions will enhance the committee's work related to technical research instrumentation, and radiation detection and measurement.

Cherrie Black
The critical infrastructure strategist was inducted into the International Network of Women in Homeland Security and Emergency Management Hall of Fame. Cherrie was selected for her achievements integrating state, local, tribal and territorial governments into critical infrastructure protection programs. She was the first female chair elected to the U.S. Department of Homeland Security's State, Local, Tribal and Territorial Government Coordinating Council.

Hussein Moradi
The wireless communications engineer provides national leadership in innovative wireless communication research and development. He has led development of the WSComm communication system to meet the needs of homeland security emergency first responders and the Department of Defense. WSComm has successfully overcome difficulties in managing radio frequency interference, interception and jamming.

ADVANCING Technology

Critical Support

INL provides critical support to the U.S. Department of Homeland Security's mission to protect industrial control systems from cybersecurity threats. The Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) is a component of the DHS National Cybersecurity and Communications Integration Center (NCCIC). Here are some highlights from their past year.

TRAINING:

ELEVEN advanced training sessions

442 advanced training participants

SUPPORT:

5,000+ copies of the Cyber Security Evaluation Tool distributed and downloaded

MITIGATION:

248 cyber incidents reported by asset owners and industry partners that were received and responded to

RECOVERY:

SEVENTY THREE vulnerability analyses provided

16 critical U.S. infrastructure sectors supported

Enhancing nuclear plant security

In 2013, INL's expertise in cyber security was recognized by multiple nuclear agencies. INL is establishing itself as the world leader in the critical emerging area of nuclear-cyber security. Based on INL's international reputation, lab experts are advising the Korea Atomic Energy Research Institute (KAERI) on design and establishment of an Instrumentation and Controls security test lab for protecting nuclear facilities. When these efforts are completed, INL will have set up centers in United Kingdom, Japan, South Korea and France in addition to now monthly international outreach as part of IAEA and NNSA work — making INL the largest contributor to control systems cyber security of any government institution in the world.

Photo courtesy: Fortum, Loviisa nuclear power plant

Supporting global nuclear security

As the world's nuclear watchdog, the International Atomic Energy Agency works for the safe, secure and peaceful uses of nuclear science and technology. Numerous collaborations with INL demonstrate the lab's leadership in nuclear safety and nonproliferation expertise.

INL provided international training for a Romanian National Training Course developed by the IAEA for nation-states requesting computer security information for nuclear facilities. The lab also conducted the first-of-a-kind nuclear facility industrial control training for IAEA, providing subject matter expertise in cyber security for nuclear facility Instrumentation & Control (I&C). INL hosted a new IAEA regional training course for state inspectors conducting cyber security assessments at nuclear facilities. Attendees from approximately 12 countries participated in the weeklong training. Dr. Khammar Mrabit, IAEA director of the Office of Nuclear Security, stressed the need for continued INL support in this critical area, requested that INL participate in planning the first nuclear cyber security conference, and asked INL to join IAEA's strategic planning team.

ADVANCING Technology

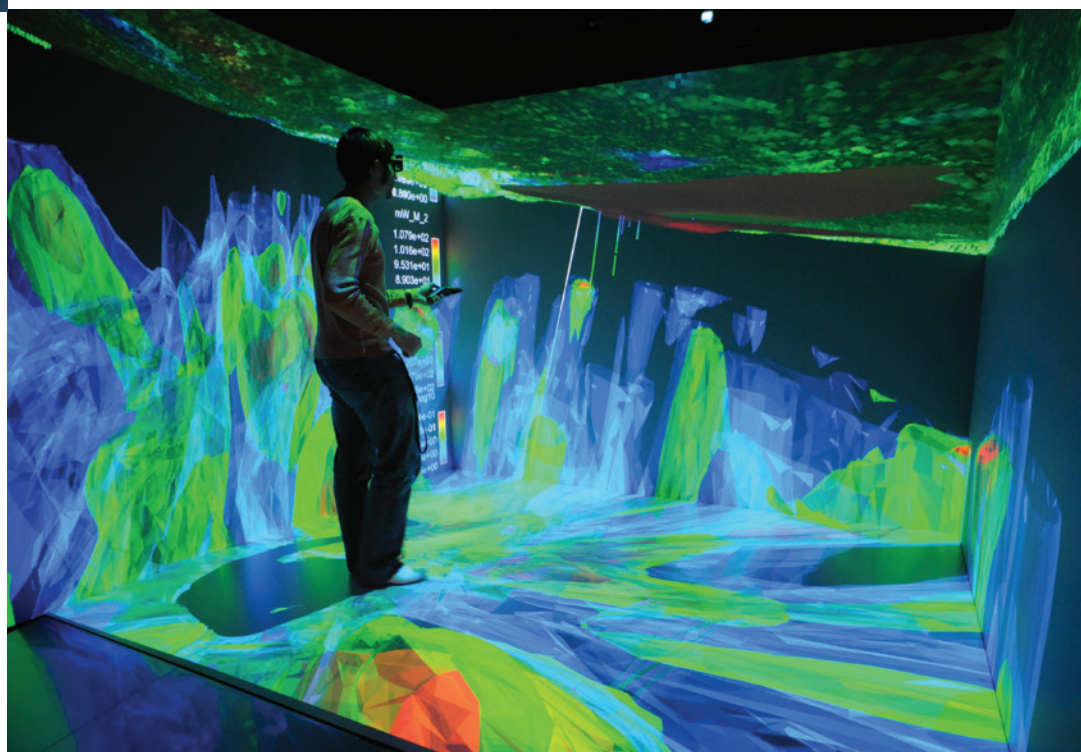
The SPS FO development team includes (left to right) Mark Stone, Aaron Wilson and Fred Stewart. Researchers can view one of FALCON's subsurface models (lower right) using the Computer Assisted Virtual Environment (CAVE) in the Center for Advanced Energy Studies (CAES) at INL.

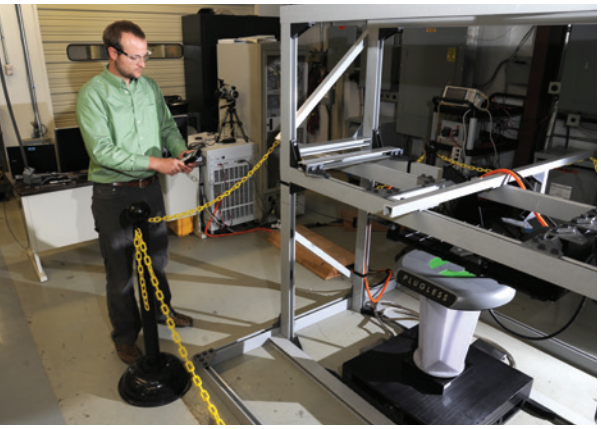
Improving industrial wastewater treatment

Industrial processes such as the natural gas extraction technique known as fracking create large amounts of concentrated wastewater. A new technology developed at INL could change that by turning wastewater back into potable water. Switchable Polarity Solvent Forward Osmosis (SPS FO) is a groundbreaking technology that combines two known processes to create a new, efficient water-filtration system. SPS FO has won several outstanding innovation awards, including a 2013 R&D 100 Award, an Idaho Innovation Award for Early-Stage Innovation, and an Outstanding Technology Development Award from the Federal Laboratory Consortium Far West Region.

Modeling geothermal energy systems

Geothermal energy taps heat within the Earth's crust to make electricity. Subsurface heat, water and permeable rock don't always converge at a single location, but Enhanced (or Engineered) Geothermal Systems supply both fluid and rock permeability at places where subsurface heat already exists. Researchers in four countries are using an INL modeling program to simulate the subsurface physics important for geothermal energy extraction. The Fracturing And Liquid CONvection (FALCON) code enables simulation that is faster, simpler and more comprehensive than previous options. The work is yielding results that can reduce risk and costs of geothermal energy development. FALCON is helping researchers evaluate geothermal energy site data, and it may soon be able to offer predictions that could help improve geothermal energy output.





Testing advanced transportation systems

Owners of plug-in electric vehicles must use a power cable to connect the vehicle's charging port to an external electric power supply. INL has released its independent testing results for the first wireless power transfer technology to be independently documented and published. The Evatran Plugless Level 2 Charging System allows a driver to start the charging process by simply parking over a charging coil, which is either installed on the ground or embedded under the surface. INL continues to conduct independent testing of PEVs and charging systems and has been recognized by the Society of Automotive Engineering (SAE) J2954 Wireless Charging Committee for its wireless charging expertise and capabilities.

Recognizing expertise

Aaron Wilson

The research chemist led development of Switchable Polarity Solvent Forward Osmosis technology that earned a 2013 R&D 100 Award, an Idaho Innovation Award and an award from the Federal Laboratory Consortium Far West Region. The technology also has two license options agreements with companies considering its commercial development for use in recycling industrial wastewater.

Jaya Tumuluru

The densification research engineer was selected by the American Society of Agricultural and Biological Engineers (ASABE) Refereed Publications Committee as the Outstanding Reviewer for the Food and Process Engineering Division in the 2012 publication year. The Reviewer Recognition program, developed by the Refereed Publications Committee, honors up to 10 outstanding reviewers each year.

Dave Parks

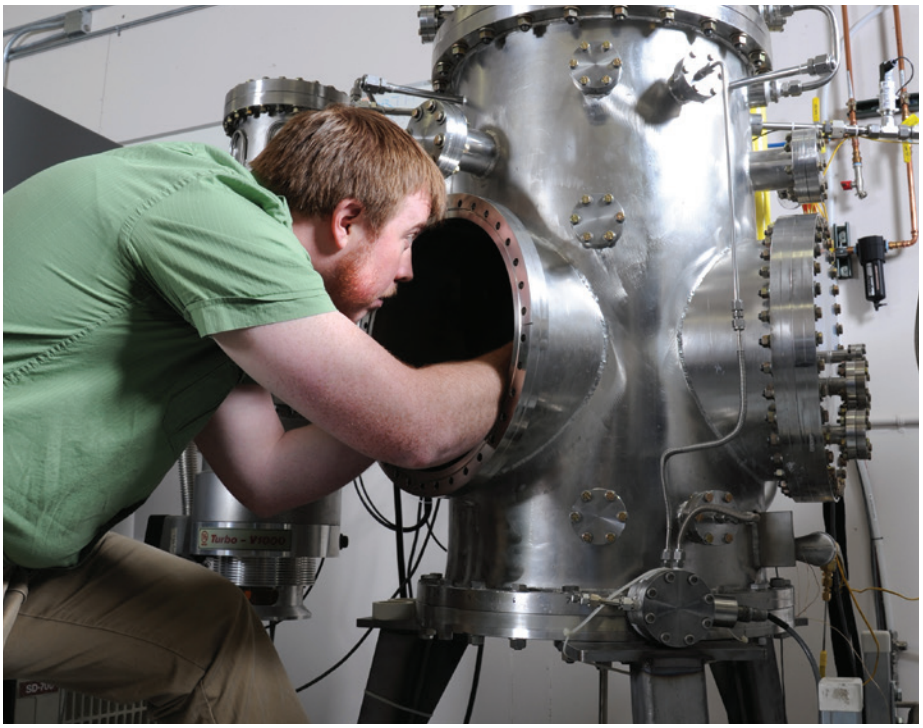
The engineer led INL work for DOE's Radiological Security and Disposition Program, which helps the government dispose of radiological materials used in medical equipment and remote power sources. This past year — the first using a new transportation strategy — the team transported and disposed of 14 devices from numerous U.S. metropolitan hospitals.

Education & University PARTNERSHIPS

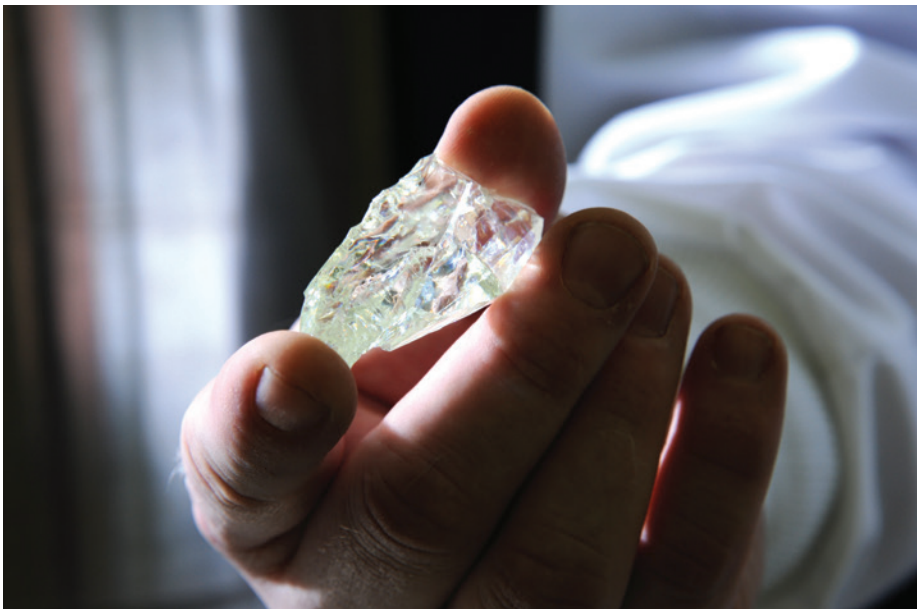
Enhancing educational opportunities

Supporting the next generation of scientists and engineers is a priority at INL. The lab's education programs support K-12 students and teachers, college undergraduate interns, graduate students, and university research efforts. Academic institutions and researchers across the nation benefit from access to INL resources, capabilities and expertise.

Sustaining a university collaborative
The Center for Advanced Energy Studies (CAES) is a partnership between INL and Idaho's three public research universities. The CAES partners have proven that a national laboratory and competing public universities can collaborate to achieve results. The CAES model enables the pooling of resources and sharing of equipment, which lets CAES researchers compete with much larger universities to win research dollars.



Winning NASA support
NASA selected a project at INL's Center for Space Nuclear Research (CSNR) as one of 12 to fund through its Innovative Advanced Concepts program. Lead researcher Nathan Jerred proposed creating a low-mass space propulsion system that could send research rockets into the solar system. By using radioisotopes and a gas propellant to create a low-cost rocket design, the propulsion system could make exploration economical enough for universities and companies to conduct space research. As a former CSNR intern, Nathan epitomizes the goals of the center's research fellowships: to enable student research projects until they gain support outside of CAES.



Growing crystals for research
A team led by Eric Burgett, an Idaho State University/CAES researcher, successfully created its first batch of pure, single uranium oxide crystals in the Research in Science and Engineering (RISE) facility in Pocatello. Researchers at Idaho National Laboratory and elsewhere are using the crystals to better understand uranium oxide – the primary fuel for the nation's nuclear reactors – and design higher-performing fuels.

Cultivating energy professionals
INL and Idaho State University, encouraged by the Nuclear Regulatory Commission, are working to train the next generation of nuclear operators and skilled maintenance workforce. The three entities jointly support a two-year nuclear operations technician program at ISU's Energy Systems Technology and Education Center (ESTEC). INL has hired several graduates from the program's first class, and five new enrollees had previously interned at INL's ATR and MFC nuclear research complexes.

Helping industry save energy
The CAES Energy Efficiency Research Institute (CEERI) launched a statewide industrial assessment center after receiving a DOE grant. Student teams at the CAES partner universities conducted free energy efficiency assessments for regional companies and manufacturing plants. The teams conducted eight visits and submitted four reports during FY 2012. Total projected energy savings identified by the teams is 1,003,464 kilowatt hours; 83,022 therms; 1,255 kilowatts; and a potential cost savings of $109,524.

350
NUMBER OF HOURS THE CAES MICROSCOPY AND CHARACTERIZATION SUITE (MaCS) WAS BOOKED FOR USE IN JUNE 2012.

700
NUMBER OF HOURS MaCS WAS BOOKED IN JUNE 2013.

15
AVERAGE NUMBER OF HOURS MaCS IS BOOKED PER DAY.

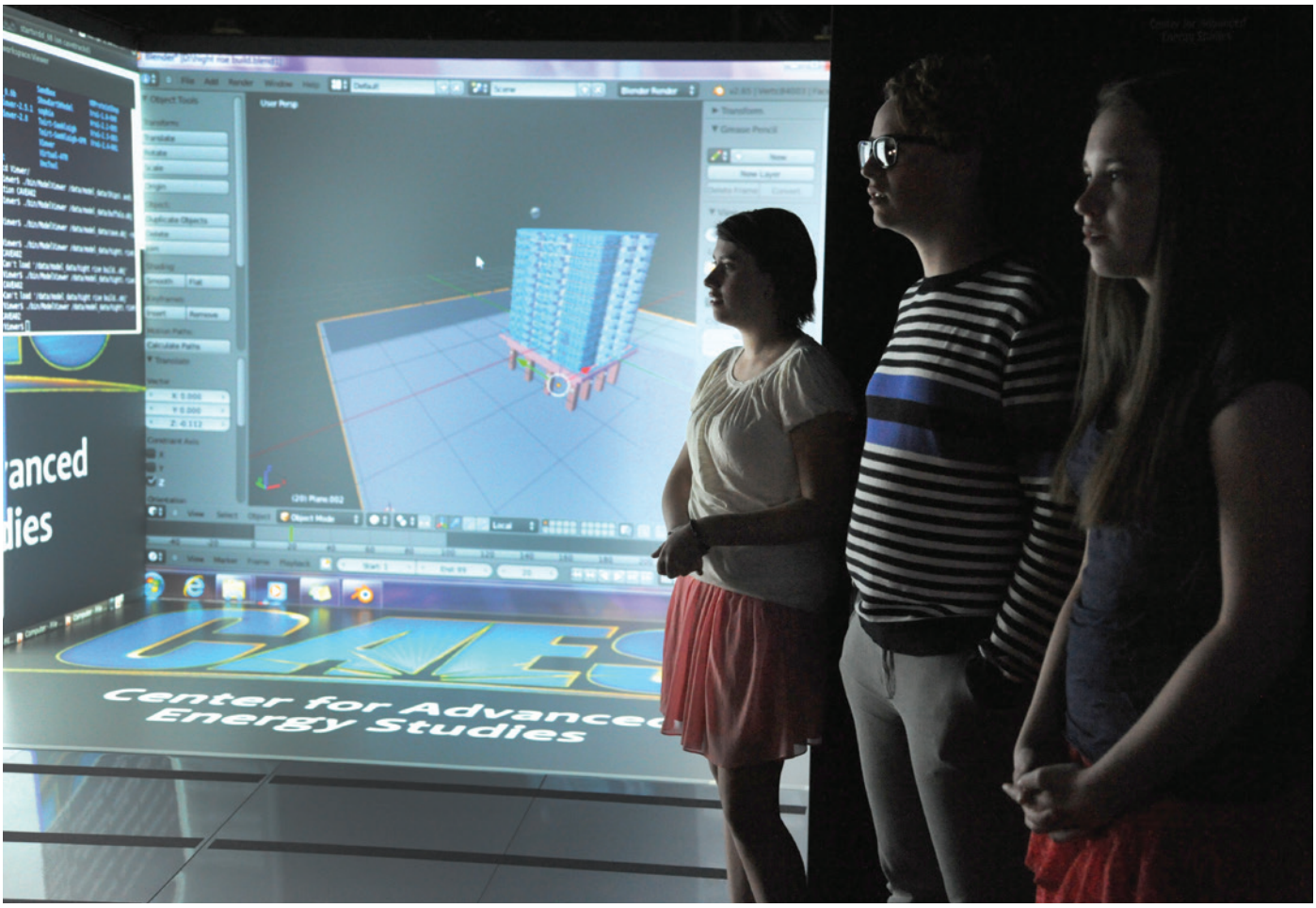
60+
NUMBER OF IDAHO UNIVERSITY STUDENTS WORKING ON CAES-RELATED (NON-NUCLEAR) RESEARCH PROJECTS IN FY 2013.

421
NUMBER OF STUDENTS ENROLLED IN NUCLEAR-RELATED DEGREE AND CERTIFICATE PROGRAMS AT THE CAES PARTNER UNIVERSITIES.

Education & University PARTNERSHIPS

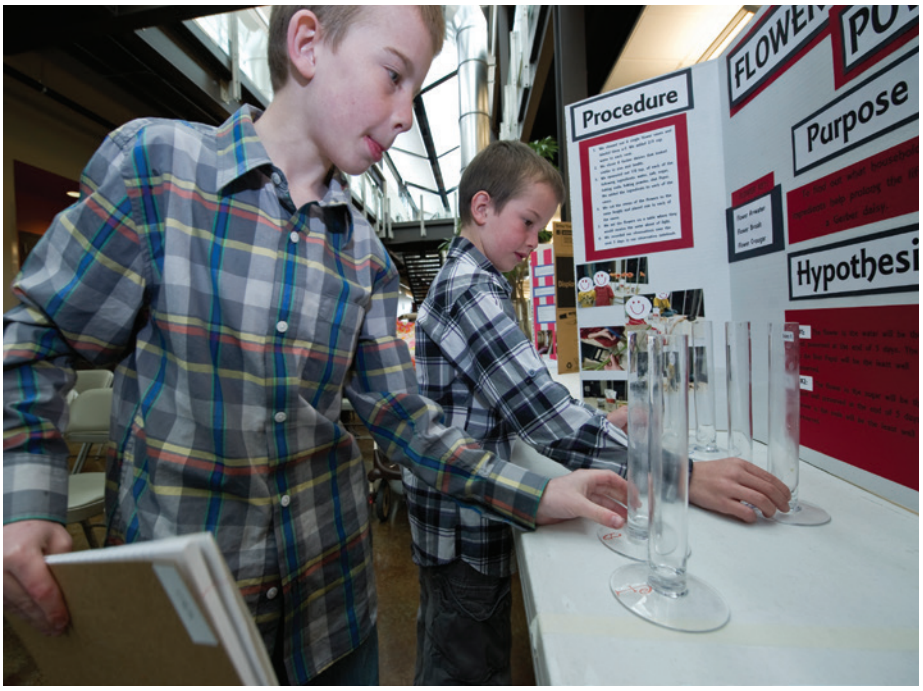
Doing math in a CAVE
Algebra II students from an Idaho Falls high school used the computer-assisted virtual environment (CAVE) at CAES to learn about the quadratic function (below). The students created animated computer models that depicted a real-world use of a quadratic equation and displayed their work in the CAVE. They also presented on their models and the math behind them to a panel of CAES students and researchers.

Encouraging energy scholars
CAES launched a new scholarship program for Idaho students interested in performing energy-related research. The CAES Energy Scholars program is a mentored internship focused on providing students from the center's partner universities with real-world experience in a variety of areas, including nuclear engineering, bioenergy, material science, modeling and simulation, and cybersecurity.



Science Fair
More than 70 students from Twin Falls to Idaho Falls participated in the Eastern Idaho Tournament of Innovation, which was held in March at the Center for Advanced Energy Studies (CAES). The event was sponsored by the Museum of Idaho, the Discovery Center of Idaho, CAES and Idaho National Laboratory.

Promoting energy education
The Idaho Falls-based Partnership for Science and Technology organization recognized Akira Tokuhiro, a University of Idaho/CAES researcher, for his contributions to energy education. Tokuhiro teaches and conducts nuclear energy research and also has served on the American Nuclear Society Special Committee on Fukushima.



DID YOU KNOW?

PV MAPPER, A NEW SOLAR-SITING TOOL DEVELOPED BY A CAES RESEARCH TEAM, IS ENTERING THE BETA TESTING PHASE. INDUSTRY PARTNERS ARE EXPECTED TO TEST THE GEOGRAPHIC INFORMATION SYSTEM-BASED SOFTWARE OVER THE NEXT YEAR. THE PROJECT IS LED BY THE CAES ENERGY POLICY INSTITUTE.

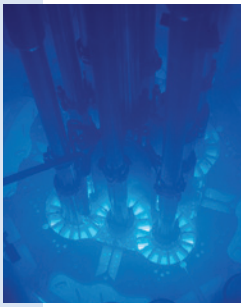
Only at INL

Unmatched capabilities

INL's isolated geography and physical infrastructure provide unique opportunities to test and demonstrate new technologies that help protect the nation's resources and advance energy security. The preceding pages have highlighted numerous capabilities that exist nowhere else in the U.S. The resources described here exemplify INL research assets that are truly unique to Idaho's national laboratory.

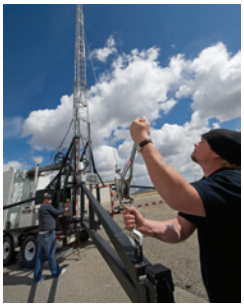
- Advanced Test Reactor
- Analytical Lab
- Fuel Conditioning Facility
- Hot Fuels Examination Facility
- Irradiation Assisted Stress Corrosion Cracking test rig
- Space and Security Power Systems Facility
- Transient Reactor Test Facility
- Utility-scale (60-mile) isolatable power grid
- Water Security Test Bed
- Wireless Test Bed
- Armor and explosives test range
- Nuclear & Radiological Activity Center (multiple areas)
- Radiological Response Training Range
- Advanced Vehicle Testing Activity data analysis
- Battery testing facilities
- Biomass Process Demonstration Unit
- Carbon Characterization Laboratory
- Dynamic Energy Storage Lab
- Human Systems Simulation Laboratory
- Industrial Control System Cyber Emergency Response Team
- Microscopy and Characterization Suite
- National SCADA Test Bed
- Specific Manufacturing Capability

National Scientific User Facilities

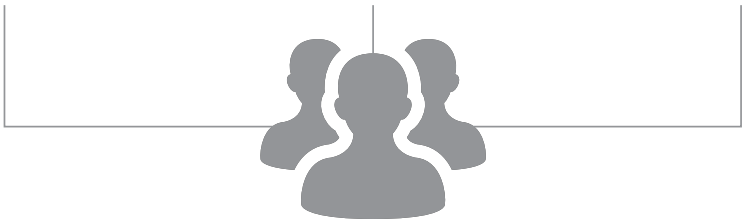


Advanced Test Reactor National Scientific User Facility

Biomass Feedstock National Scientific User Facility



Wireless National User Facility



By the numbers:

890 SQUARE MILES OF ISOLATED FACILITIES IN IDAHO DESERT

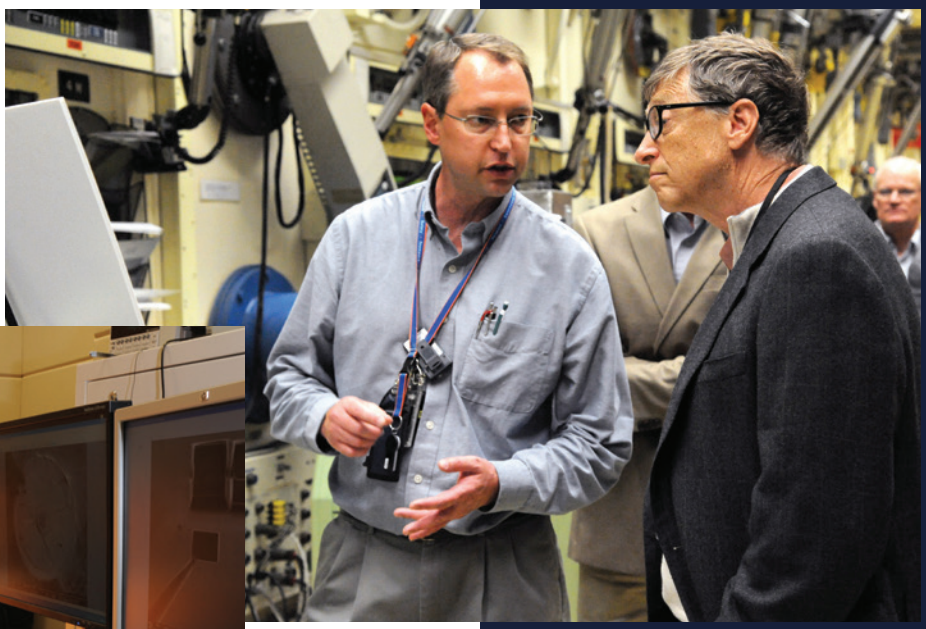
ONE NUMBER OF NATIONAL LABS REPORTING DIRECTLY TO DOE'S OFFICE OF NUCLEAR ENERGY

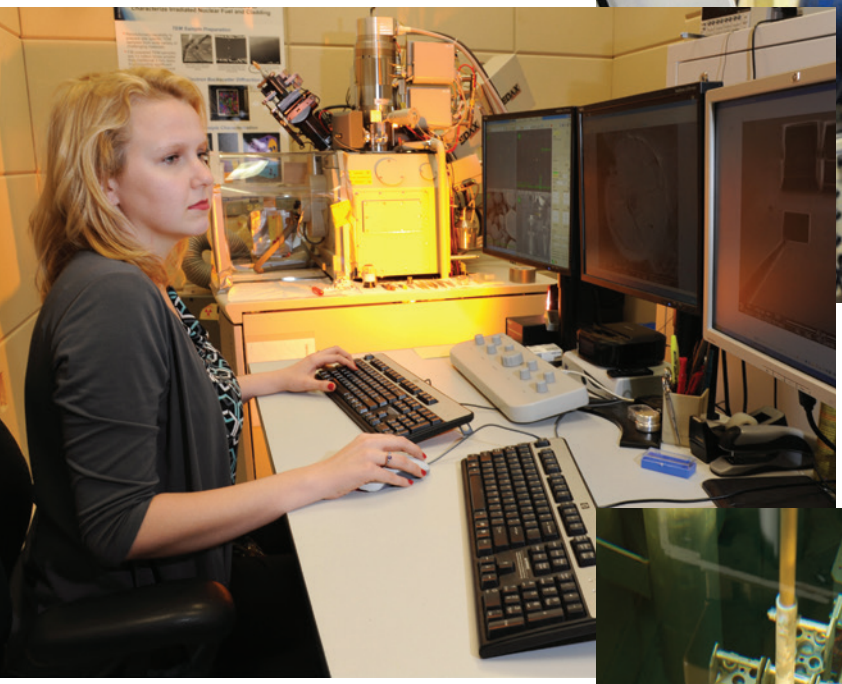
52 NUMBER OF MOSTLY FIRST-OF-THEIR-KIND NUCLEAR REACTORS DESIGNED AND BUILT AT WHAT IS NOW INL

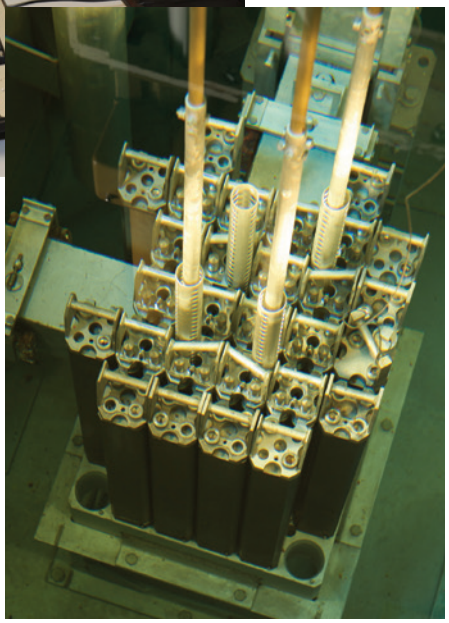
10,000 ROUGH NUMBER OF PEOPLE WHO TOUR INL FACILITIES EACH YEAR

ABOUT INL

In operation since 1949, INL is a science-based, applied engineering national laboratory dedicated to supporting the U.S. Department of Energy's missions in nuclear and energy research, applied science, and national security.







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